Application of HSPF-AGCHEM Module within the WMS for the LeSueur Basin

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PURPOSE: This technical note presents the results of the incorporation of the Hydrologic Simulation Program–Fortran (HSPF) AGCHEM modules into the Watershed Modeling System (WMS). HSPF allows simulation of processes that affect water quality. Often the most significant of these processes are agriculture and chemical processes that take place on agricultural land segments. Such processes include application of pesticides and fertilizers. Included in HSPF are three modules that collectively are referred to as the AGCHEM modules: the PEST (pesticides) module, the NITR (nitrogen) module, and the PHOS (phosphorus) module. The AGCHEM modules allow users to model the processes that take place as part of agricultural practices.

Clearly, these modules are indispensable in modeling a watershed for water quality. Thus, the interface to HSPF developed in WMS was modified to contain tools for the access and control of the AGCHEM modules. The purpose of this paper is to provide an overview of the implementation of the interface to the AGCHEM modules in WMS.

OBJECTIVES: The objective of this research was to incorporate the AGCHEM module of HSPF into WMS and to demonstrate the utility of the WMS-HSPF AGCHEM modules in developing nutrient balances to better understand nutrient cycling, mass balance, and runoff contributions from both agricultural and nonagricultural land segments. The demonstration was conducted on the LeSueur Basin watershed located in the Upper Mississippi River Basin. Other potential sites include those located within the Minnesota River Basin, as well as other sites where total maximum daily loads (TMDLs) need to be determined.

BENEFITS: This demonstration highlights the potential advantages of adopting the WMS-HSPF AGCHEM modules for developing comprehensive nutrient balances within the Upper Mississippi River Basin. This application will further demonstrate the utility of adopting the WMS-HSPF model as a tool for evaluating the effects of best management practices (BMPs) on water quality improvements within the basin. Comprehensive nutrient mass balances will reflect potential watershed areas for improvements as well as assessing both positive and negative water quality impacts as the result of land use changes.

AGCHEM IMPLEMENTATION: The data to drive the PEST, NITR, and PHOS modules in HSPF are organized into several data tables, which are input to HSPF through the user input control (UCI) file. The first objective in implementing the AGCHEM support in WMS was to manage these data tables. To accomplish this objective, an internal database in WMS was set up to hold the AGCHEM data. This database may be populated in two ways:

- Opening/reading a UCI file into WMS from a previous HSPF model.
- Creating an HSPF model in WMS and entering the AGCHEM parameters.

In the first option, a UCI file is read into WMS, and if the AGCHEM modules are active, the data are parsed from the file and placed in the WMS database. These parameters can then be viewed/edited; the method implemented for viewing/editing will be discussed later in this document. If the UCI file does not contain AGCHEM data, then the model is read into WMS and the AGCHEM module may be activated and added to the model from the UCI file. In the second option, an HSPF model is created in WMS, and the AGCHEM modules can be activated and data can be entered into the database.

Once the AGCHEM modules have been activated in WMS, the database can be written to a UCI file. Any HSPF model that contains AGCHEM data, whether it was read into WMS or created in WMS, can be written to a new UCI file, which contains the AGCHEM data and is ready to run in HSPF.

AGCHEM DATA VIEWING/EDITING: Data for the PEST, NITR, and PHOS modules can be viewed or edited in WMS through a series of dialog boxes. Each parameter or option available in the AGCHEM modules can be accessed in these dialogs, thus providing the user with full control of the processes to be modeled by HSPF. The PEST, NITR, and PHOS dialogs will be discussed below.

PEST Module Interface. The PEST module of HSPF allows simulation of up to three pesticides. For each pesticide to be modeled, several data tables must be populated. These data tables contain information on the pesticide and the soil to which it is applied. Access to these parameters is provided in WMS through the dialog shown below:

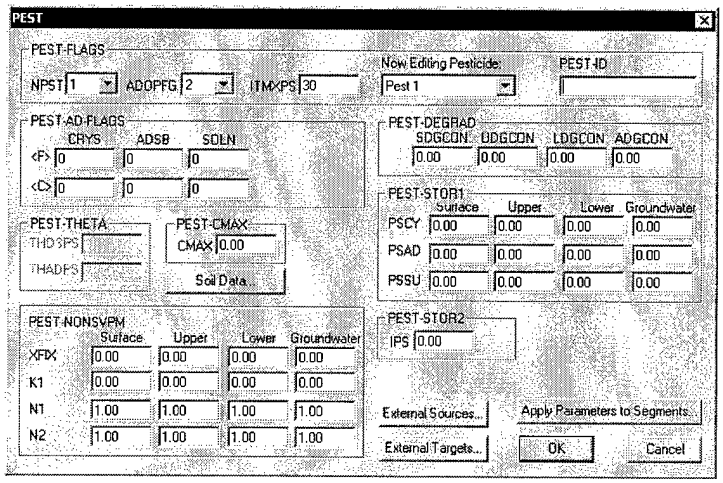

Figure 1. Pest module dialog

The parameters for each pesticide can be edited/viewed by selecting which pesticide (Pest 1, Pest 2, or Pest 3) is to be displayed. Then all fields of the dialog will be filled with the parameters from the AGCHEM database. Note that all tables for the PEST module are shown

directly in this dialog except for the SOIL DATA table. This table can be shared among several modules and is accessed by clicking on a button in the PEST dialog.

In addition to access to the database of parameters, this dialog provides links to tools in WMS for assigning time-series data to the PEST module as input or selecting time-series data to be output from the PEST module. These options can be accessed by clicking the "External Sources" and "External Targets" buttons.

NITR Module Interface. The NITR module of HSPF is somewhat more complicated than the PEST module. Thus, a slightly different approach was taken in building dialogs to access the data for this module. The main dialog to access these parameters is shown below:

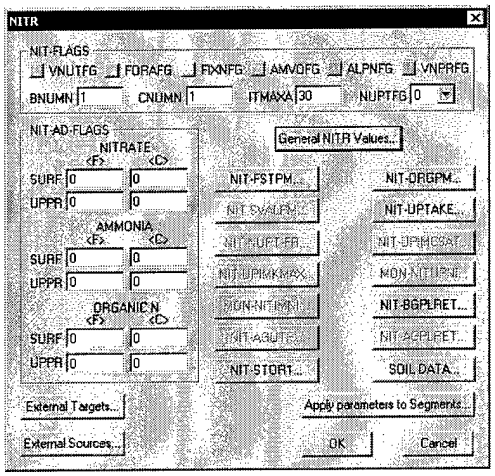

Figure 2. NITR module dialog

The dialog above contains the option flags, which may be set in NITR. Then, based on these flags, buttons are activated that access the data for each necessary data table (NIT-FSTPM, for example). When one of the buttons is clicked, a simple dialog appears that allows the user to view/edit parameters for the given table. This approach is helpful in the case of this module because of the variety of table combinations available to model the nitrogen processes. WMS aids in activating the required tables so that the user does not omit one.

Just like the PEST dialog, this dialog provides links to tools in WMS for assigning time-series data to the NITR module as input or selecting time-series data to be output from the NITR module. These options can be accessed by clicking the "External Sources" and "External Targets" buttons.

PHOS Module Interface. The PHOS module of HSPF is similar to the NITR module, but not quite as complicated. Thus, a similar approach has been taken to allow access to the parameters of the PHOS dialog. The main PHOS dialog in WMS is shown below:

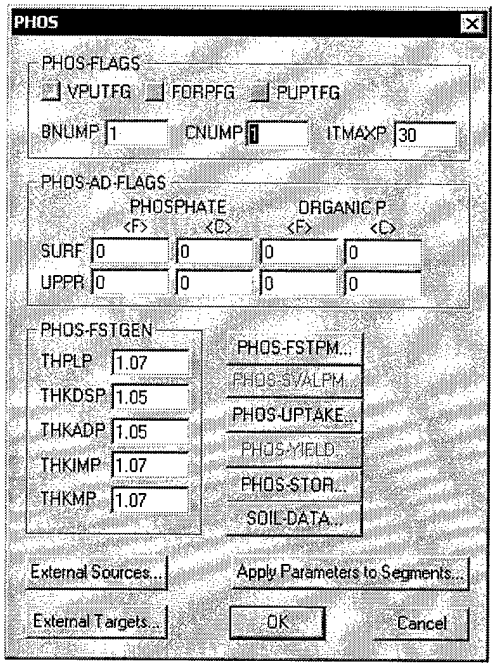

Figure 3. PHOS module dialog

The dialog above contains the option flags that may be set in PHOS as well as fields for the data tables always required by the PHOS module. Similar to the NITR dialog, buttons are then activated based on the option flags set to indicate which tables are required by HSPF. When one of the buttons is clicked, a simple dialog appears that allows the user to view/edit parameters for the given table. Thus, WMS aids in activating the required tables so that the user does not omit one. Just like the PEST and NITR dialog, this dialog provides links to tools in WMS through clicking the "External Sources" and "External Targets" buttons.

PRELIMINARY TESTING OF INTERFACE: Once the AGCHEM capabilities of HSPF were successfully incorporated into the WMS, it was tested utilizing data collected within the LeSueur watershed located within the Upper Mississippi River Basin in Minnesota. For this project, an AGCHEM UCI on the LeSueur watershed was set up using the Walnut Creek UCIs (Donigian et al. 1993) and Chesapeake Bay UCI (Donigian et al. 1990) as templates. The new AGSETUP.UCI was modified from the BASE.UCI developed in a previous LeSueur watershed simulation (Donigian and Duda 1997). In the previous study, the LeSueur watershed was segmented (Figure 4) and the water quality constituents (BOD, NH4, NO2+NO3, PO4, and fecal coliform) in the outflows from land segments were simulated using simple relations with water and/or sediment yield (PQUAL of Module PERLND and IQUAL of Module IMPLND).

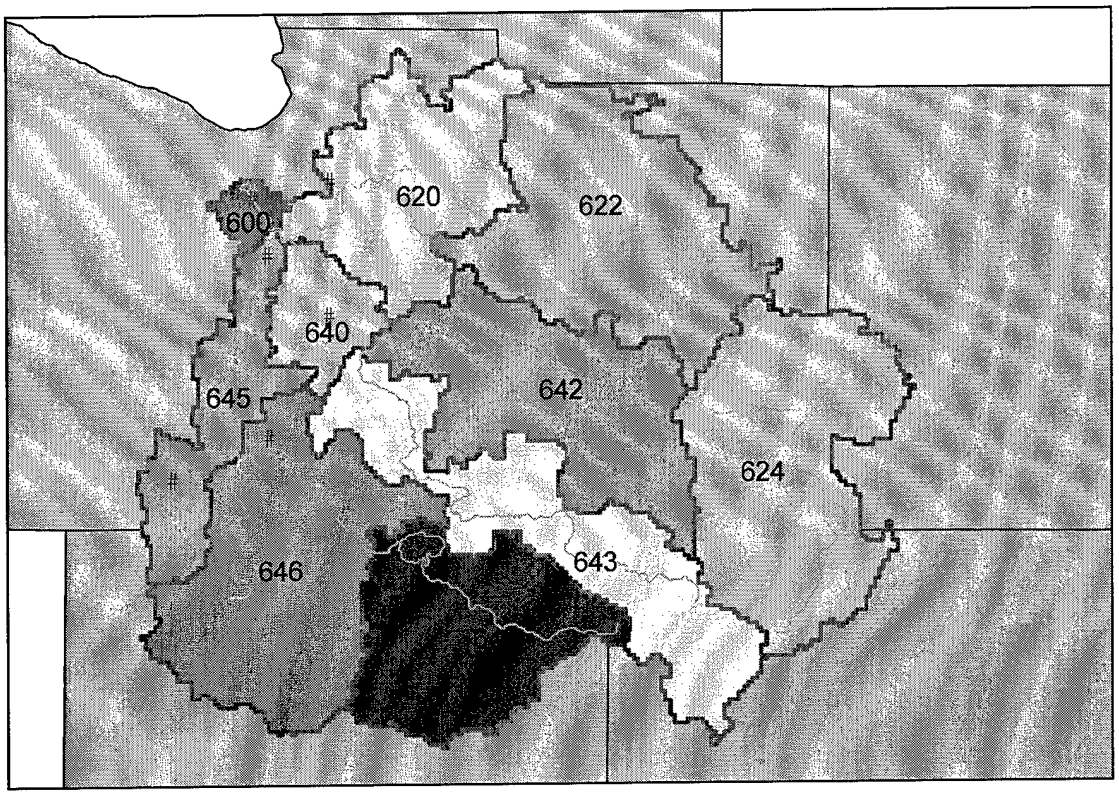

Figure 4. Segmentation of the LeSueur watershed

To simulate more detailed soil reactions and transport of pesticides and nutrients in the soil profile of a land segment, however, the AGCHEM module must be used. In AGSETUP.UCI, the PERLND sections PEST, NITR, and PHOS are used to simulate pesticide and nutrient behaviors on high-till and low-till croplands, instead of the PQUAL section. Using the AGCHEM module, pesticide and nutrient applications are defined in the SPEC-ACTIONs block.

As noted above, the AGCHEM UCI was set up as an example to test the inclusion of the AGCHEM module of HSPF in the WMS. For this purpose, the AGSETUP.UCI was tested, and model parameters as well as chemical application rates were slightly adjusted. Initial calibration was conducted, even though model calibration was not included in the scope of this effort.

AGCHEM UCI SETUP AND APPLICATION: The AGCHEM module in HSPF was set up to simulate nitrogen, phosphorus, and pesticide in high-till and low-till croplands. BOD and FECAL COLIFORM in those two croplands and all constituents (BOD, FECAL COLIFORM, NH3, NO2+NO3, and PO4) in other land uses are still simulated using the PQUAL module in HSPF. The user control input (UCI) file corresponding to the AGCHEM setup was named AGSETUP.UCI. The AGSETUP.UCI was derived from BASE.UCI. The created UCI for the LeSueur watershed was imported into the WMS to determine the effectiveness of the WMS-HSPF AGCHEM interface.

The UCI file was successfully loaded into the WMS. The system correctly interpreted the AGCHEM HSPF code and the corresponding numerical data were correctly displayed in the

WMS input fields. Within the WMS, the entire HSPF UCI file can be modified to reflect changes in the value fields for BMPs or other land feature changes within the watershed. After any desired changes are made to the UCI file, it is saved within the WMS. The WMS writes the UCI to a directory selected by the user of the system. In our test, the LeSueur UCI file was properly outputted from the WMS. Finally, the LeSueur UCI files, in combination with a corresponding WDM file, were used for an HSPF run. The HSPF run was properly executed utilizing the UCI file created within the WMS.

RESULTS: The HSPF model was successfully integrated into the WMS. The system is able to read existing HSPF UCI and WDM files as well as create new ones. The creation of new HSPF files allows users of the system the ability to easily generate the required HSPF run files from existing data. This will aid the user in system delineation, parameter assignment/estimation, and execution of the HSPF program. Tools within the system can then be used to evaluate and compare alternative watershed water quality management strategies.

The LeSueur watershed in Minnesota was used to test the functionality of HSPF-WMS. The first step in the process was to read in an existing UCI file. Figure 5 represents the LeSueur watershed in a tree format. This is a typical representation of UCI files brought into the WMS from an outside source. The parameters read into the system were compared to the UCI values created by conventional methods. This comparison demonstrated that HSPF-WMS was properly reading existing UCI files. Following this step, several parameters were modified within HSPF-WMS and the WMS-HSPF with AGCHEM was run. Simulations included flow and several water quality constituents.

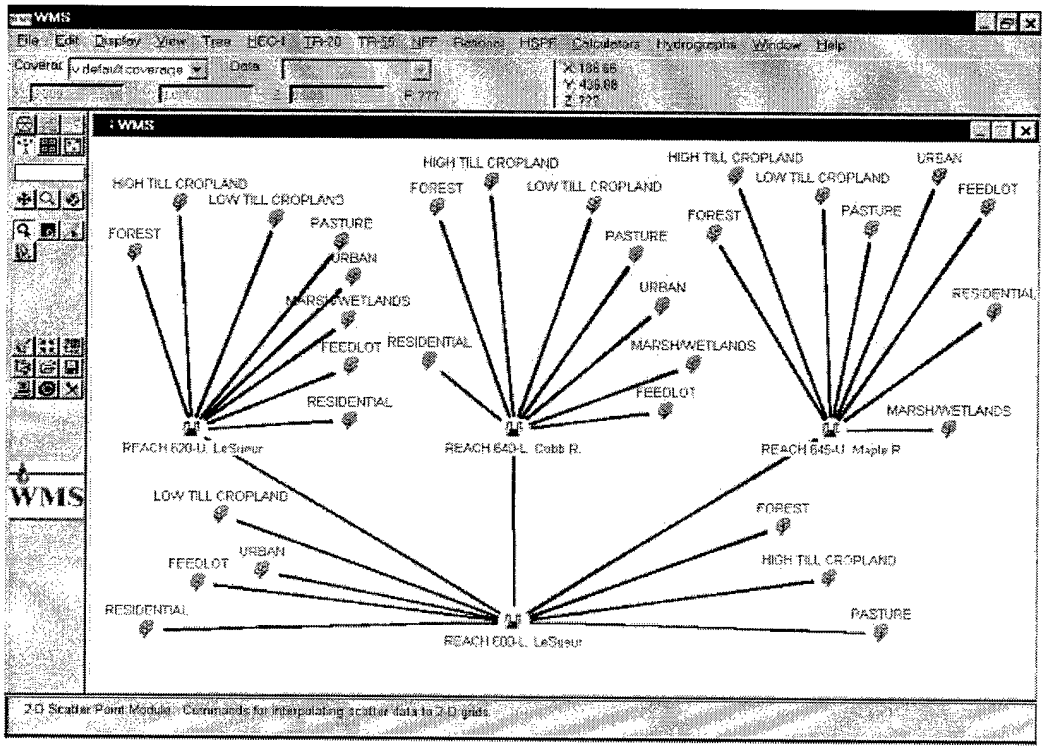

Figure 5. Tree diagram of the LeSueur HSPF UCI file

Figures 6-9 show the hydrologic calibration at Rapidan, Minnesota, which represents the Lower LeSueur River at Reach 600. Figure 6 shows the observed versus calibrated depth of flow from 1986 to 1992. Figures 7, 8, and 9 demonstrate the confidence of the calibration. From these figures, it can be concluded that the calibration showed good agreement between the simulated and observed values. The daily time flow time series generally shows good agreement, and the frequency curves match well.

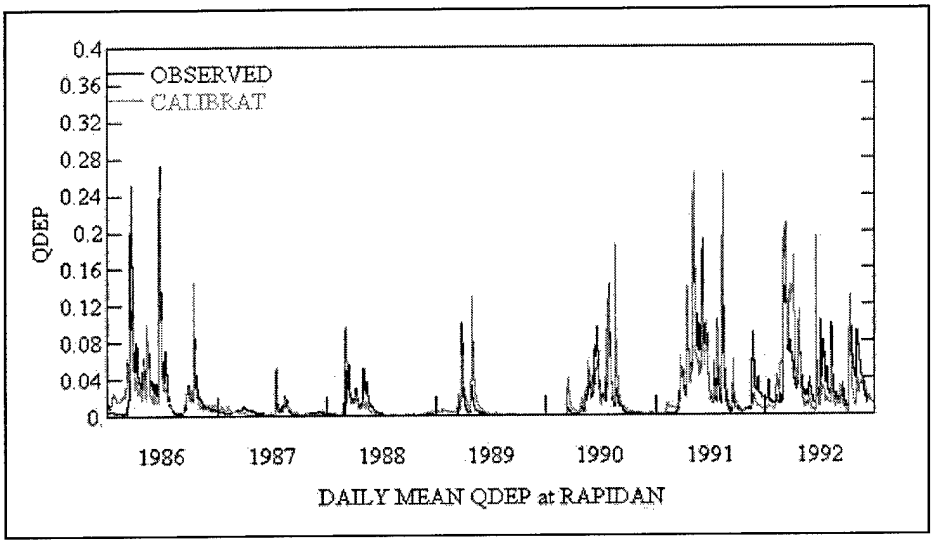

Figure 6. Flow depth (ft) versus time at Rapidan, Minnesota

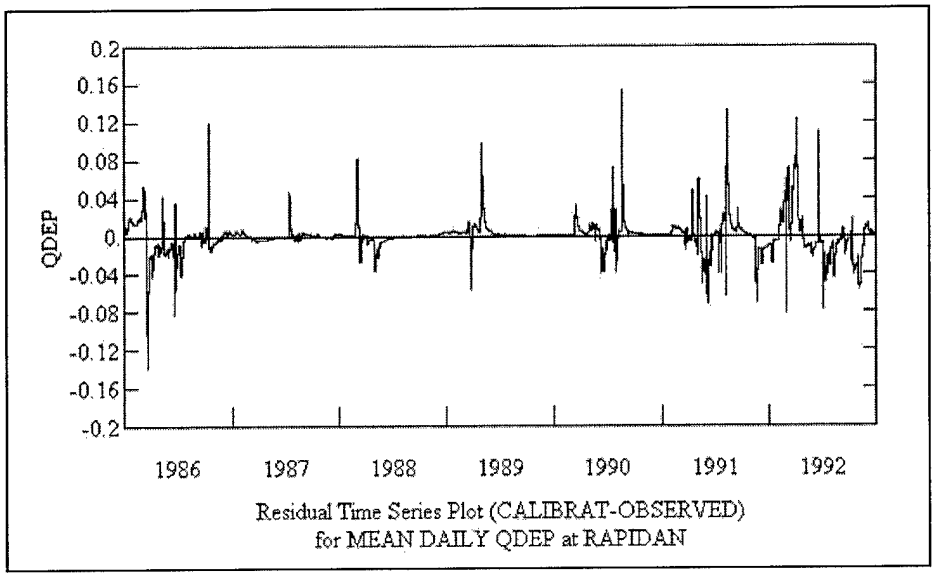

Figure 7. Residual plot for flow depth at Rapidan, Minnesota

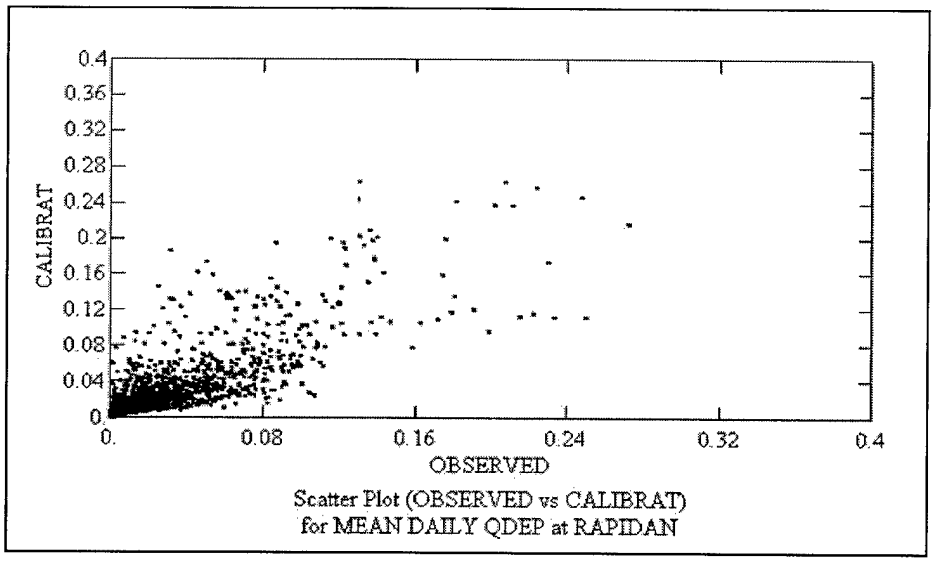

Figure 8. Scatter plot of observed versus calibrated flow depth at Rapidan, Minnesota

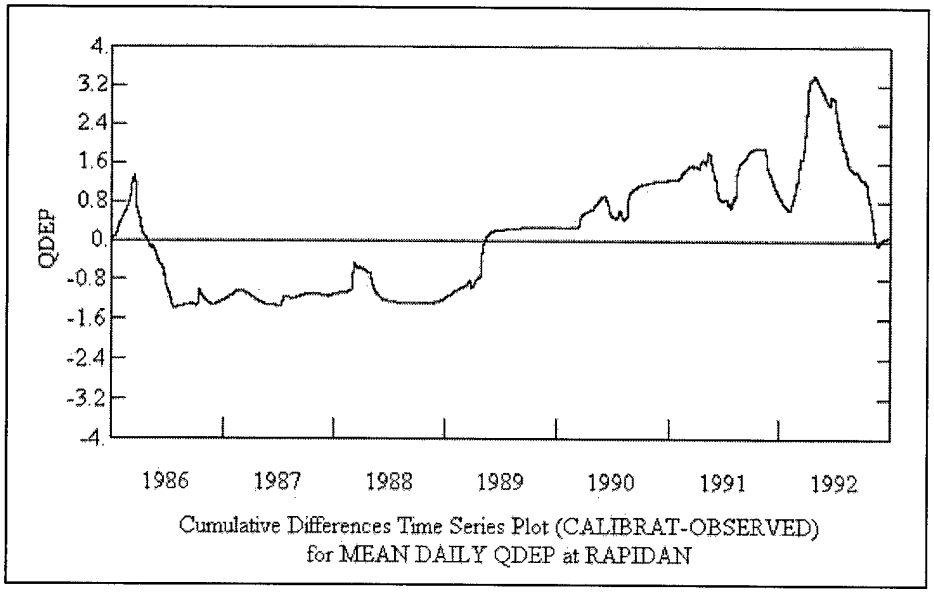

Figure 9. Cumulative difference plot for flow depth at Rapidan, Minnesota

Water quality constituents were enabled following the successful hydrologic calibration. Due to a lack of observed data, observed versus calibrated values could not be obtained for this portion of the study. However, simulations compared the calibrated base conditions to conditions with riparian buffer zones implemented within the watershed as a BMP. Figure 10 shows the projected improvement of the implementation for total nitrogen in mg/l. Peak values are reduced by more than 50 percent due to the addition of buffer strips in the watershed. This demonstrates the potential improvements in water quality that could be made within the watershed to meet TMDL objectives.

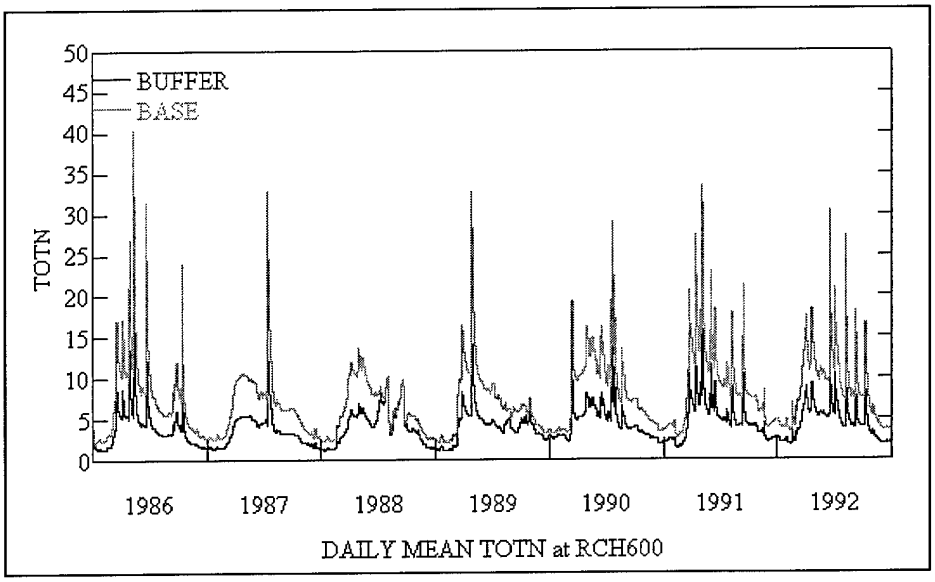

Figure 10. Total nitrogen concentrations (mg/l) for the buffer and base case scenarios at Rapidan, Minnesota

CONCLUSIONS: The AGCHEM module within HSPF was successfully integrated into the WMS. The system is able to read existing HSPF UCI and WDM files as well as create new ones. The creation of new HSPF files allows users of the system to easily generate the required HSPF run files from existing data. This will aid the user in system delineation, parameter assignment/estimation, and execution of the HSPF program. Tools within the system can then be used to facilitate the evaluation and comparison of alternative watershed water quality management strategies.

The HSPF interface in the WMS is a more complete solution to the problems of HSPF modeling in the TMDL development process. WMS allows the development of an HSPF model for any watershed – such a watershed can be developed in WMS or imported from a GIS application. With WMS, the watershed may be segmented automatically, several input parameters computed, and input reviewed and edited using simple Windows dialogs. Further, WMS provides tools to manage WDM dataset files essential to HSPF modeling.

The LeSueur watershed in Minnesota was used to test the functionality of HSPF-WMS. The first step in the process was to read in an existing UCI file. The parameters read into the system were compared to the UCI values created by conventional methods. This comparison demonstrated that HSPF-WMS was properly reading existing UCI files. Following this step, several parameters were modified within HSPF-WMS and the model was run. Simulations included flow and several water quality constituents.

The AGCHEM interface in the WMS accomplishes two objectives:

- Data management of the PEST, NITR, and PHOS modules. This includes reading and writing the data to/from a UIC file.

- Access to the data in the AGCHEM modules through simple dialogs that provide full control over the PEST, NITR, and PHOS modules.

The tools in WMS provide control and customization not offered in other software solutions. Given that TMDL studies have been mandated for many watersheds with many different analysis needs, such control is indispensable. HSPF has the power and flexibility to model many situations; the problem to this point has been in finding a simple and reliable way to set up the HSPF model. WMS resolves these problems.

RECOMMENDATIONS: The WMS-HSPF AGCHEM tools should be applied to a watershed for which more data have been collected. This would allow for a more detailed calibration as well as a comprehensive evaluation of water quality processes occurring within the watershed.

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